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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

Chairman William E. Kennard
Federal Communications Commission
445 12th Street, SW
Washington, D.C. 20554

Ex Parte Filing

Re: CS Docket No. 00-96

Dear Chairman Kennard:

On July 14, 2000 the Association of America's Public Television Stations (APTS), the Public Broadcasting Service (PBS) and the Corporation for Public Broadcasting (CPB) jointly submitted comments in the above captioned proceeding supporting the creation of rules to implement Section 338 of the Communications Act of 1934, as added by the Satellite Home Viewer Improvement Act of 1999. In adopting this provision, Congress determined that in return for a compulsory copyright license to carry local broadcast stations, DBS carriers have an attendant public interest obligation to carry all the stations, including the noncommercial educational television ("NCE") stations, in those markets where local service is provided pursuant to the compulsory copyright license. This obligation is particularly important for NCE stations, which have a federal mandate to serve the entire American public and lack the retransmission consent rights that facilitate carriage negotiations outside the statutory obligation.

On August 4, 2000, APTS, PBS and CPB responded in reply comments to various claims by DBS operators that, despite the clear command of Section 338 and the intent of Congress, DBS local carriage obligations should somehow be reduced to accommodate limits in satellite carriage capacity. APTS, PBS and CPB demonstrated in these reply comments that the DBS operators had dramatically overstated without justification the extent to which DBS capacity would be devoted to local station carriage pursuant to Section 338. APTS, PBS and CPB demonstrated, further, that by 2002, with the use of spot-beams and improved compression technology in the Ku-band, coupled with some use of advanced technology in the Ka-band, it would not be unduly burdensome for carriers to provide access to all local signals in all markets in which local service is provided, consistent with the SHVIA.

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List A B C D E

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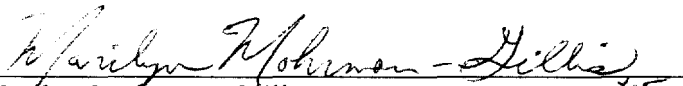
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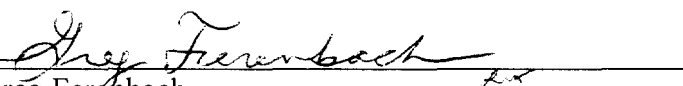
APTS recently commissioned a report by Strategic Policy Research to examine in depth the issue of satellite carriage capacity to further inform the Commission's deliberations in this rulemaking proceeding. This report substantially supports our prior conclusions regarding capacity, finding that carriage of all local television stations in those markets where local service is provided is possible in the Ku-band coupled with some use of the Ka-band— technology that is available today and that does not require undue financial burdens. The report concludes:

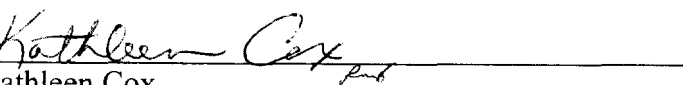
Our analysis of the technical feasibility suggests that virtually complete carriage of local television signals— whether digital or analog— is well within the productive capacity of DBS systems that can be realistically deployed and efficiently exploited using available technical knowledge and spectrum assignments. This result can be accomplished consistent with maintenance of quite substantial capacity for other purposes, including delivery of large quantities of other types of video programming, different types of data and broadband Internet access service.

(Strategic Policy Research, "Channel-Carrying Capacity of DBS Systems," p. 4.) Therefore, carriage of multiple noncommercial stations in markets where DBS carriers provide local service would impose few technical or economic burdens on the DBS industry. APTS, PBS and CPB hereby submit this report into the record in CS Docket No. 00-96 as an *ex parte* filing to assist in the Commission's deliberations in this proceeding.

Respectfully Submitted,


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Greg Ferencbach
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CHANNEL-CARRYING CAPACITY OF DBS SYSTEMS

PREPARED FOR AMERICA'S PUBLIC
TELEVISION STATIONS

November 17, 2000

EXECUTIVE SUMMARY

Congress has directed the Federal Communications Commission (“FCC”) to promulgate rules that would require DBS carriers to carry upon request the signals of all television stations located within a local market by January 1, 2002, if they choose to carry any station(s) in the market under a compulsory copyright license. While conceding that such rules are mandated by statute, the satellite service providers have argued, *inter alia*, that such requirements impose “an *impossible* burden” that would put “*excessive* demands on capacity,” and that “satellite channel capacity would be *overburdened*.” This report challenges the validity of that argument by providing an analysis of current and anticipated channel-carrying capacity of DBS systems.

There are currently two DBS operators in the United States—DirecTV and EchoStar Communications —serving about 13 million subscribers from Ku-band satellites operating at the 101°, 110° and 119° West Longitude orbital locations, each of which affords coverage of the entire United States. The spectrum at each orbital location in the Ku band is divided up into 32 transponders, each capable of carrying about 30 Mbps of digital information. DirecTV owns all 32 transponders at the 101° location, 3 transponders at the 110°, and 11 transponders at the 119° location. EchoStar owns 29 transponders at the 110° location, 21 transponders at the 119°, as well as several transponders at locations offering partial coverage of the United States. A combination of digital compression and statistical multiplexing will allow the carriage of about 10 television channels per transponder, leading to a combined capacity for Echostar and DirecTV of about 960 video channels.

Because the disputed carriage obligations do not begin until 2002, it is important to identify potential increases in capacity. There are several possible developments in DBS systems that will impact capacity. We discuss the five that appear to have the most promise. To the extent there are additional developments not considered here, the analysis embodied in this report provides a conservative view of future capacity.

1. *Utilization of spot beams to divide downlink signals.* Use of so-called “spot-beam” technology affords a means to directionalize downlinks and, through this technique, effectively reuse the same frequency several times. Under conservative operating assumptions, universal deployment of

spot beams in Ku-band operations *alone* would triple the system capacity available for carriage of local signals. The implementation of spot-beam technology is currently in the process of being deployed by both DBS operators, and should not entail significant costs increases.

2. *Deployment of Ka-band systems.* The FCC has designated some spectrum in the higher frequency Ka band for DBS applications. Ka-band systems, since they operate at higher frequencies, need smaller antennas, and hence can produce more spot beams and greater frequency reuse than the Ku band can accommodate. A single Ka-band satellite with spot beams will be able to carry the analog broadcasts of every local station in the United States with capacity left over. Since each of the existing carriers has been awarded two Ka-band slots, this technology offers the potential for full carriage of virtually all possible local signals, whether digital or analog. Additionally, if a *single* Ka-band satellite were operated as a “carrier’s carrier,” as has been proposed by Local TV on Satellite, then both DirecTV and EchoStar could use it for local channels, while retaining their Ku-band satellites for their national program services and other services such as Internet access.
3. *More aggressive signal compression.* Over the last decade, there have been notable advances in signal compression technology that allow delivery media to carry significantly greater throughput than previously possible. It is difficult to predict the exact magnitude of future compression developments. However, if the past serves as a guide, prospects for further efficiency gains remain and can likely be implemented without major modifications to existing satellites or customer equipment.
4. *Increases in the number of realized bits per Hertz.* The number of bits that can be transmitted within a given bandwidth can be expected to expand as technology improves. Indeed, the Ka-band systems currently being designed are likely to realize about 39 Mbps in 30 MHz of bandwidth, 30 percent more than that realized in current systems, standardized in the early 1990s. A variety of companies are making significant

contributions in terms of enhancing the performance of satellite networks. One would expect the capacity impacts of these technical advances to be realized as old plant wears out and is replaced.

5. *Capacity-sharing for provision of common services.* Satellite operators may arrange to share some satellite transponder capacity to transmit non-proprietary programming, including local stations, to subscribers of both operators. This arrangement would greatly economize on the capacity dedicated to programming carried by both operators by sharing a single transmission.

We also consider the implications of High-Definition Television (“HDTV”), or “digital broadcasting,” for carriage requirements and capabilities. Whereas about 3 Mbps are needed to deliver acceptable analog signals, about 19.4 Mbps will be required for carriage of digital signals. We assume, conservatively, that each transponder on a Ku-band satellite can accommodate one digital signal and three analog signals. This implies that DirecTV can currently carry 46 digital signals and 138 analog signals, while EchoStar can currently carry 50 digital signals and 150 analog signals. As with analog, digital signal carriage would be significantly enhanced by spot beams, capacity sharing, *etc.* The next-generation Ka-band transponders can be designed to more easily accommodate digital signals. Assuming each of the 46 transponders per Ka-band satellite can handle two digital signals, each Ka-band satellite can serve 92 digital signals. Spot-beams with a reuse factor of eight will multiply each satellite’s effective transponders to 368 (46 X 8), able to carry 736 local digital signals.

Our analysis of technical feasibility suggests that virtually complete carriage of local television signals—whether digital or analog—is well within the potential productive capacity of DBS systems that can be realistically deployed and efficiently exploited using available technical knowledge and spectrum assignments. This result can be accomplished consistent with maintenance of quite substantial capacity for other purposes, including delivery of large quantities of other types of video programming, different types of data and broadband Internet access service. Our conclusion rests primarily on timely deployment of advanced satellites in the Ku and Ka bands utilizing spot-beam technology that appears to be already underway.

1. INTRODUCTION

The channel-carrying capacity of Direct Broadcast Satellite (“DBS”) video program delivery systems is an important issue for public policy. Congress has directed the Federal Communications Commission (“FCC”) to promulgate rules that would require DBS carriers to carry upon request the signals of all television stations located within a local market by January 1, 2002, if they choose to carry any station(s) in the market under a compulsory copyright license.¹ While conceding that such rules are mandated by statute, the satellite service providers have argued, *inter alia*, that such requirements impose “an *impossible* burden” that would put “*excessive* demands on capacity,” and that “satellite channel capacity would be *overburdened*.”²

This report provides an assessment of the channel-carrying capacity of DBS systems. We begin with a brief description of the DBS systems currently in place. We identify the operators and describe the services they provide and the productive facilities they have currently deployed. We identify and describe the primary technological parameters of the systems and their import for carriage capabilities. We then examine the potential for improvements in the carrying capacity of DBS systems in the future. Use of spot-beam antennas, deployment of Ka-band systems, advances in compression software and multiplexing systems, and sharing of satellite resources through capacity-sharing arrangements or industrial consolidation all offer some promise of enhancement in carrying capacity. We analyze the import of such enhancements for increases in local station carriage as well as delivery of Internet access and other data services. We

¹ See 1999 Satellite Home Viewer Improvement Act (“SHVIA”), Section 338. (“Carry One/Carry All”).

² See *Comments of the Satellite Broadcasting and Communications Association*; and *Comments of DirecTV* (emphases added). See also “Sats pitch ‘must carry,’” *Broadcasting & Cable* (July 31, 2000).

also consider the implications of High-Definition Television (“HDTV”) or digital³ broadcasting for carriage requirements and capabilities.

2. CURRENT (Ku-BAND) SYSTEMS

There are currently two DBS operators in the United States—DirecTV and EchoStar Communications —serving about 13 million subscribers. DirecTV is the larger of the two, serving about twice as many customers as EchoStar. Both operators utilize Ku-band satellites licensed for DBS at downlink frequencies located between 12.2 and 12.7 GHz. These satellites are parked in orbit above the equator at an altitude of about 22,300 miles, where they remain fixed relative to the earth’s surface. They operate at sufficiently high power to deliver a commercially effective signal to 18-inch parabolic reflectors located at customers’ premises (assuming other supply requirements are satisfied, *e.g.*, a physically unimpeded signal path).

The 500 MHz of licensed spectrum permit the use of 32 transponders at each orbital location. Each transponder can carry about 30 Mbps of digital information. Ku-band DBS satellites are spaced 9° apart to allow signals from different satellites to be differentiated easily. FCC licenses specify the number of transponders an operator can utilize at a particular orbital location. As described presently, the two operators share transponder capacity in some orbital locations, and could conceivably share satellites as well, although they appear not to do so at present.⁴

The orbital locations at 101°, 110° and 119° West Longitude can each afford coverage of the entire United States. Both EchoStar and DirecTV have satellites and licenses at these locations. DirecTV owns all 32 transponders at 101°, 3 at

³ There has been some confusion in terminology as the transition to digital television takes place. All satellite signals are digital, as are some current cable signals, even though they carry the same information as the standard analog 6 MHz signal. The 19.4 Mbps digital signal designed for carriage of HDTV pictures can alternatively be used to carry a multiplicity of standard TV signals in digital form, each requiring as few as 3 Mbps or less. For purposes of this discussion, we will use the term “digital” to mean a 19.4 Mbps digital signal.

⁴ While the maximum capacity at any orbital location is 32 transponders, more than one satellite per location may be required to supply sufficient power for all the authorized transponders.

110° and 11 at 119°. EchoStar controls 29 transponders at 110° and 21 at 119°. In addition, EchoStar owns some transponders at other locations that afford partial coverage of the United States.

Both operators' primary service utilizes simple parabolic dishes that provide access to a single satellite. DirecTV also offers other services (*e.g.*, DirecTVPLUS) that utilize elliptical antennas to provide access to satellites in adjacent orbital positions. EchoStar promotes a version of its DISH system that uses an elliptical antenna capable of receiving signals from both its 110° and 119° satellites.

The 30 Mbps of capacity from each transponder can be used as the operator desires. About a year ago, DirecTV appeared to carry seven channels per transponder, corresponding to about 4 Mbps per channel. That was sufficient to provide high-quality pictures for movies and other applications, including most sports events. Generally speaking, the MPEG-2 compression scheme provides VCR-quality TV at about 1.5 Mbp. Broadcast quality has required approximately 4 Mbps. If many channels are offered over the same broadband facility, as is the case here, then statistical multiplexing techniques can be used. These techniques allow bits from a channel where there is little action to be used by one with greater action at a given instant, which can substantially increase effective capacity consistent with provision of acceptable picture quality. Using these techniques, the current systems (now) appear to operate at about ten channels per transponder, or 3 Mbps per channel.⁵

3. EXISTING CAPACITY

Based on their current service offerings, we can estimate the broadcast channel-carrying capacity of the existing DBS systems.

⁵ This level of compression does not come without cost. If too many signals concurrently need many bits, or if some signals are of low quality in a way that adds to the apparent rate of change of the pictures, there may not be enough bits to go around and the picture quality of all channels using a given transponder may suffer.

3.1. DIRECTV

DirecTV's basic service offers approximately 198 television channels and 31 music channels. In addition, DirecTV offers access to local TV signals in 28 markets on its primary satellite at 101°. It offers four stations in each of 22 markets, and five stations in each of six markets, for a total of 118 local stations. Summation of these numbers indicates that DirecTV supplies 316 TV channels plus 31 music channels on its 32 transponders at 101°, each capable of carrying 30 Mbps. On the assumption that music channels require 1 Mbps each, the total bandwidth required by the music channels is 31 Mbps, *i.e.*, approximately equivalent to a single transponder.⁶ That leaves 31 transponders for utilization by the 316 video channels, implying an allocation of about 3 Mbps for each channel—an arrangement that apparently provides adequate signal quality.

DirecTV also offers access to six local markets using its satellites at 110° and 119°, which requires customers to utilize an elliptical antenna. If four stations per market are assumed for these six markets, then the total number of local stations that DirecTV carries is 142. They have also announced that they will add some more local markets in the coming months using these satellites. DirecTV also offers Internet access, called PCDirect, with a maximum download rate of 400 Kbps, with upstream signals sent via telephone. It is not clear how much capacity is devoted to this service. A maximum throughput of 400 Kbps does not, of course, equate to continuous transmission at that rate. Internet transmissions tend to be sporadic and bursty. Transmissions are individualized so that each user must be allocated some amount of the system's carrying capacity. If the service were to attract a large number of users, their transmissions could occupy a significant fraction of the available capacity—probably mostly on the secondary satellites.

3.2. ECHOSTAR

EchoStar advertises over 500 channels of TV, Internet Access and HDTV from its DISH system. Since DISH utilizes a total of 50 transponders operating over the U.S., this corresponds to an average of ten channels per transponder, or about 3

⁶ Although there is no doubt that 1 megabit is more than enough capacity to support high-quality music signals, DirecTV's channelization system may require that all signals have the same nominal bit rate. This would imply a slightly lower bit rate per channel for all other channels.

Mbps per channel. DISH carries local TV signals in 32 markets, which are presumably included in the total; four stations in each of 24 markets, five stations in each of six markets and six stations in each of two markets, for a total of 138 local stations, close to the number served by DirecTV. Some markets are served from the 110° satellite, while others are served from the 119° satellite.

4. POTENTIAL PRODUCTIVITY ENHANCEMENTS

There are at least five ways in which DBS system operators could plausibly increase the channel-carrying capacity of their systems:

1. Utilization of spot beams to divide downlink signals;
2. Deployment of Ka-band systems;
3. More aggressive signal compression;
4. Increases in the number of realized bits per Hertz; and
5. Ku-band capacity-sharing for provision of common services.

These are not mutually exclusive and, thus, we would anticipate that DBS system operators will proceed to make improvements along all or many of these fronts to expand the current carrying capacity of their systems.

We now discuss each of these five means of capacity expansion, in turn.

4.1. UTILIZATION OF SPOT BEAMS TO DIVIDE DOWNLINK SIGNALS

Use of so-called "spot-beam" technology affords a means to directionalize downlinks and, through this technique, effectively reuse the same frequency several times. "Transponders" for the purpose of this discussion are devices that receive and transmit information in a particular portion of the spectrum. Each transponder occupies about 30 MHz of spectrum at one polarity, which will support a certain digital bit rate. Under current broadcast arrangements, only one transponder can be used at each frequency and polarity in a particular orbital location. If directional antennas are used, a number of transponders can operate at the same frequency and polarity, greatly multiplying the capacity of the system to carry signals that are focused on particular locations. Thus, signals directed at Los Angeles could use the same frequency and polarity as signals directed at New York. The size of the beams is determined by the size and configuration of the antennas on board the satellites. At Ku band, it should be possible to deploy antennas that can be focused on an area with a diameter of 500 miles or less.⁷ With such an arrangement, the U.S. can be covered with approximately 18 spot beams. If these were arranged so that no beams at the same frequency and polarity are aimed at adjacent areas, to minimize interference, then a frequency reuse factor of three can easily be realized.⁸ This arrangement would *triple* the system capacity available for carriage of local signals. Spot-beam technology would thus permit carriage of about 900 local stations (for EchoStar—if 200 of its 500 channels were devoted to national broadcasts and the remaining 300 reused three times), *i.e.* equivalent to about 70 markets occupied by about 75 percent of the nation's population, if all stations in every market served were carried.

The implementation of spot-beam technology, while promising substantial productivity enhancement, does not entail significantly higher costs as it does not

⁷ This is a conservative estimate, based on uniformly-sized areas. In practice, antennas will be designed to focus on smaller or larger areas depending upon specific geographical and demographic conditions. The antennas to be used on the satellite, if standard mechanical reflectors, cannot be changed after launch, although they could conceivably be redirected if that capability is installed before launch. If phased-array antennas are used, they can also be redirected, but it is not clear whether the size of the beams can be altered.

⁸ The geometry of such an arrangement would suggest a reuse factor of four. We will assume conservatively that three are utilized.

entail that great an advance in the technology deployed. Some satellites already use spot beams to reach specific locations and others are planned.⁹ The total costs of satellites embodying spot-beam capabilities, including launch and insurance, are not likely to be appreciably higher than costs of the current satellites. Although implementation of spot-beam capabilities requires satellite upgrades, it does not affect customer equipment.

4.2. Ka-BAND SYSTEMS

In 1996, the FCC allocated spectrum in the 17.7-18.8 and 19.7-20.2 GHz downlink bands for geostationary fixed satellite service. Part of this spectrum is shared with terrestrial microwave applications, but the FCC has allocated a total of 720 MHz—in two groupings, 500 MHz and 220 MHz—to Fixed Satellite Service. These higher frequency systems allow the satellites to be spaced only 2° apart, which allows for a great many more orbital slots. Furthermore, spot beams can be more narrowly focused without the need for outsized antennas.

We can estimate the carrying capacity of a single one of these satellites as follows:

Assume that the 500 MHz-portion is divided into 32 transponders, as is the case in the Ku band, with 14 more in the additional 220 MHz, for a total of 46 transponders. The modulation system (more advanced than that currently in use with Ku-band satellites), will allow 39 Mbps per transponder. Assuming that about 3 Mbps is required for each standard TV channel, as is the case with existing systems, then a satellite can carry 12 standard-definition TV signals per

⁹ Spot beam systems in the Ku band will be deployed by both EchoStar and DirecTV in the next two years. EchoStar VII and VIII, planned for launch in December of 2001 at 119° and 110°, respectively, will have spot beams capable of accessing 60 markets. EchoStar IX, planned for launch in 2002 in the 121° orbital slot, will be a combined Ka- and Ku-band satellite designed for two-way Internet access in partnership with Gilat, as well as access to consumer locations. The licenses for this satellite are not DBS licenses, so presumably they will be operating at different frequencies in the Ku band than the DBS systems. DirecTV has ordered a spot beam Ku-band satellite, denoted DBS 4S, to be launched into orbit at 101 degrees in the fourth quarter of 2001. See DirecTV Press Release (12/8/99): "DIRECTV-4S, the Hs 601HP satellite will be the first spacecraft in the DIRECTV fleet to use highly focused spot beam technology that will enable DIRECTV to expand its local channel offerings in metropolitan markets throughout the country;" and EchoStar Press Release (2/23/00): "EchoStar VII and VIII will be advanced, high-powered direct broadcast satellites. Each will include spot-beam technology that will allow DISH Network to offer local channels in as many as 60 or more markets across the United States."

transponder, implying a total of some 552 channels. Deployment of spot-beam technology, of course, substantially enhances the capacity available for carriage of local stations. It is possible to generate spot beams as narrow as 0.3° , covering an area about 120 miles in diameter, with the signal attenuated by only 5 db at the perimeter. This arrangement will afford good reception everywhere inside the coverage area, but will not allow the same frequency to be used in adjacent areas. Reuse of every third beam leads to a reuse factor of about 8.¹⁰ Thus, if a single satellite were used solely for distribution of local TV signals, this would allow for a total of 4,416 signals and leave the Ku satellites entirely free for alternative uses.¹¹ This is, of course, far more capacity than is needed to carry all the local television stations operating in the U.S. Indeed, the carriage capacity implied by an even more conservative reuse factor of four would still suffice to provide complete carriage.

If a *single* satellite were operated as a "carrier's carrier," as has been proposed by Local TV on Satellite, then both DirecTV and EchoStar could use it for local channels, while retaining their Ku-band satellites for their national program services and other services such as Internet access.¹²

All of the preceding discussion rests on analysis of the results of deploying a *single satellite*. If EchoStar and DirecTV remain independent and use one satellite each for local coverage (wasteful as that may be), they both could more than carry all the television stations in the United States. Both carriers have been

¹⁰ Local TV on Satellite plans to build Ka-band spot beam satellites that will serve approximately 800 19.4-Mbps signals, implying a reuse factor of about 9.

¹¹ EchoStar and DirecTV both have authorization from the FCC to use orbital slots in the Ka band. EchoStar has slots at 83° and 121° , while Hughes has slots at 99° and 101° . These can be accessed jointly with nearby Ku-band satellites using elliptical antennas not much larger than those currently in use for the DISH and DirecTVPLUS systems.

¹² As previously noted, this by no means exhausts the opportunities for capacity-sharing and conservation of scarce spectrum carrying capacity. Channels have the character of "quasi-public goods" in technical economic terms because they exhibit the property of "non-rivalry in consumption." That is to say that my downloading of a particular signal does not preclude (leave less) for you to download. Whenever MVPD satellite operators wish to distribute the same program material, they can potentially economize on resource expenditures by finding contractual or organizational means to share the costs of the required resources rather than wastefully duplicate them. Alternatively, each carrier could launch such a satellite and have capacity to provide complete carriage of local signals, but this would seemingly entail a substantial and unnecessary duplication of effort.

awarded two orbital slots in the Ka band, and if they used them both, the capacity available to them would be doubled. If the satellites were shared, of course, four satellites could provide four times as much capacity to reach local areas, far more than is required for complete analog TV coverage.

The power of spot-beam technology to facilitate the delivery of local channels is obviously enormous. The numbers we calculate (on conservative assumptions) are themselves so much larger than the demand from local stations that even were the design assumptions optimistic (rather than pessimistic), there would still appear to be more than sufficient capacity to enable complete carriage of local signals in their respective markets.

4.3. MORE AGGRESSIVE SIGNAL COMPRESSION

Over the last decade there have been notable advances in signal compression technology that allow delivery media to carry significantly greater throughput than previously possible.¹³ The DBS carriers' current systems, which compress

¹³ See, for example, Peter J. Brown, "Digital Video Compression: On a Roll," Dow Jones Interactive (4/10/00):

The greater emphasis on encoder efficiency and performance is unmistakable. Digital encoding and video compression technologies are defining and having an impact on all the activities that go on around them, both upstream and downstream....Barry Hobbs highlights fundamental changes: 'We have much more powerful chips to work with thanks to very large-scale integration (VLSI), and this has resulted in better motion estimation and much lower bit rate yields. With MPEC 2 encoder chips, which are much better, so too are both our own implementations and third-party implementations...Whereas SDTV might require 8 Mbps today, a year from now pure efficiency gains will reduce that figure to 6.4 Mbps to 7.2 Mbps. This follows *the trend of a 10 to 20 percent increase in encoding efficiency each year*'...Encoders are software-driven machines, and the software today is incredible (emphasis added).

See also "Transmission Tweaking: Taking Satellite Network Performance to New Heights," Dow Jones Interactive (1/10/00):

Encoding is all done at far better rates today. Over the past year or so, the digital video component of HDTV was running about 18 to 18.1 Mbps out of the total ATSC stream of 19.39 Mbps. Now we are seeing the data rate for video dropping to 14 Mbps for things such as sports...As far as HDTV movies are concerned, we have seen the video in 1080i/24 drop down as low as 10 to 12 Mbps, while 720p video is now down in the 7 to 8 Mbps range. And just as we

(footnote continued)

video signals to about 3 Mbps, can carry about 10 video channels on a transponder. It is difficult to predict the magnitude of future improvements derived from advances in compression technology since past trends do not necessarily presage future trends. If the past supplies a reasonable guide to future prospects, then there remains a prospect for further gains along this dimension, although at 3 Mbps for broadcast TV, compression algorithms may be reaching a point of diminishing returns. To the extent that there is potential for such improvements, they can likely be implemented without major modifications to existing satellites or customer equipment.

For purposes of our assessment, we do not project any specific productivity improvement derived from advances in compression technology. By so doing, we thus impart a conservative bias to our assessment.

4.4. INCREASES IN REALIZED BITS PER HERTZ

The number of bits that can be transmitted within a given bandwidth depends on a great many factors including, *inter alia*, the available bandwidth, the available power, the sensitivity of receiving equipment, noise levels in the channel, *etc.* As technology improves, it can be expected that this ratio will improve. Indeed, the Ka-band systems currently being designed are likely to realize about 39 Mbps in 30 Mhz of bandwidth, 30 percent more than that realized in current systems, standardized in the early 1990s. A variety of companies are making significant contributions in terms of enhancing the performance of satellite networks. Greater reliability and efficiency translates to enhanced productivity and lower costs making for more attractive and economical offerings for consumers.

Achieving increases in the amount of digital information that can be transmitted is likely to require that the modulation system be reconfigured, requiring new satellites and new receivers. Although the expected service lives of satellites is as much as fifteen years, it can be expected that receivers, like most consumer electronic equipment, will be replaced sooner. Thus new receivers that can accept

are seeing the video rates coming down, similar changes in audio are also taking place.

both old and new protocols can begin to be sold, and new satellites can utilize the improved modulation systems.

While a thoroughgoing re-engineering of the existing systems could capitalize on improved know-how and produce significant productivity enhancements, it might well entail a significant expenditure of resources. Where systems lack maturity, the requisite expenditure of resources (for systemic as opposed to incremental changes) might not prove economic in the near term. Certainly, one would expect productivity-enhancing technical advances to be embodied in new capital equipment when it is deployed (and sooner to the extent economic opportunities for realizing nearer-term benefits on an incremental basis present themselves). And the greater the magnitude and scope (*viz.*, value) of such advances, the sooner it will likely prove economic to replace existing capital plant.

Nevertheless, for purposes of producing a conservative assessment, we again attach no specific near-term prospective payoff from an increase in the number of bits realized per Hertz for Ku-band systems.

4.5. CAPACITY SHARING

As stated above, the two current operators, DirecTV and EchoStar, together control 96 transponders that can deliver signals to the entire continental United States.¹⁴ As we have noted, assuming 10 channels per transponder, this affords a total capacity of 960 channels. If the satellite systems themselves were separated from the marketing operations of the two companies (an organizational innovation not unheard of—think of recent structural reforms in the natural gas and electricity industries or, for that matter, the FCC’s former regulation of telephone companies’ supply of “video-dialtone”), then the satellite transponder capacity could be used in common by both operators (or perhaps even a larger number of operators).

Suppose 100 channels were set aside for each operator’s proprietary programming—channels that they would like to distribute nationally, but do not

¹⁴ In addition, EchoStar controls 19 transponders at 61.5°, capable of reaching the eastern U.S., and 24 transponders at 148°, capable of reaching the west U.S., Alaska, Hawaii and the Pacific Islands. These cannot be readily utilized in conjunction with the satellites at 101°, 110° and 119° as they require a separate antenna. Our analysis focuses on the transponders available in the three orbital locations that deliver signals to the entire continental U.S.

want or need agreement from the other operator; and 100 channels were jointly used for provision of commonly broadcast national channels (say, "The Food Network" or "Discovery"). That would leave 660 channels available for delivery of local TV signals.¹⁵ If all stations in served markets are carried, the top 42 markets (accounting for about 62 percent of TV households¹⁶) could be served.

"Capacity sharing" would entail few significant technical alterations and would appear to afford a very effective way of making more effective and economic use of scarce spectrum resources. More efficient *economic* arrangements that permitted a more efficient technical rationalization of carriage could thus very substantially expand the number of *different* signals the current system infrastructure might support.¹⁷

The FCC has gone to great lengths to encourage shared use of local telephone subscriber loops (as well as utility poles, ducts and conduit that contain those loops) and, in this way, to increase competition and the effective output of services delivered to consumers via those facilities. Application of the same principles might be similarly expected to enhance the value of the effective throughput delivered through DBS facilities reliant upon scarce spectrum resources.

4.6. SYNOPSIS

As should by now be evident, there are a number of different ways in which the effective carrying capacity of the DBS systems could be significantly enhanced. The effective productivity of the currently allocated spectrum resources could be substantially enhanced through deployment of spot-beam technology. The deployment of Ka-band systems would greatly augment current capacity. It is also reasonable to anticipate that further improvements in compression

¹⁵ Assuming spot beams as well as an efficient rationalization of carriage through capacity-sharing arrangements, this would be more than sufficient for carriage of all local TV stations.

¹⁶ 1997 to 1998 Nielsen U.S. Television Household Estimates.

¹⁷ Synergistic economies generated by avoidance of duplicative effort are a commonplace of long standing in the economic analysis of broadcasting. See P.O. Steiner, "Program Patterns and Preferences, and the Workability of Competition in Radio Broadcasting," *Quarterly Journal of Economics* v. 66 (May 1952) (please note date of publication.); and B.M. Owen and S.S. Wildman, *Video Economics* (1992), pp. 64-100.

capabilities as well systemic improvements in the ability to increase the number of bits that can be transmitted with given bandwidth will enhance productivity. Finally, there is the potential for any number of different types of organizational arrangements (“reforms”) that would facilitate sharing of channel capacity on existing systems, avoiding spectrally wasteful duplication.

5. IMPLICATIONS FOR DIGITAL CARRIAGE

Our discussion thus far has focused on carriage of the analog signals of local television stations. These signals can be compressed into relatively low bit-rate digital formats, so that only about 3 Mbps are needed to deliver a signal of acceptable technical quality.

We are, of course, currently in the midst of a major industrial transition to digital television, one entailing substantial resource investments both by the government and by broadcasters. HDTV is a system that will deliver higher-quality pictures to television viewers, but it requires a new transmission format. The format has evolved over a number of years, although not without considerable controversy. It basically calls for a 19.4-Mbps digital signal and a modulation scheme (8-VSB) that allows it to be carried within a standard 6 MHz analog TV broadcast channel.¹⁸ This system, designed to utilize the broadcast spectrum efficiently, does not, unfortunately, help the DBS carriers. DBS systems currently receive 6 MHz analog signals from program sources, and encode them into digital form using MPEG-2 coders that produce digital bit streams of approximately 3 Mbps. These are then combined with other signals to produce a 30-Mbps bit stream that is sent to the satellite. If a DBS provider is presented with a 19.4 Mbps digital signal from the program originator, it obviously must treat it differently. Although it may be possible to do some compression of this signal,¹⁹ 19.4 Mbps is

¹⁸ Cable systems, with their well-controlled operating medium, have found it possible to adopt a modulation system (“QAM”) that will allow them to carry two digital signals, or 39 Mbps of digital information in each 6 MHz analog TV channel.

¹⁹ See, for example, Peter J. Brown, “Transmission Tweaking: Taking Satellite Network Performance to New Heights,” Dow Jones Interactive (1/10/00):

Three years ago or so, for example, the typical null packet in a digital satellite transmission was viewed by the satellite industry as something that was simply
(footnote continued)

already an extremely highly compressed signal, given the amount of information that needs to be carried to produce a high definition picture. We will assume in the following discussion that DBS carriers will, at least in the near term, need to carry the full 19.4 Mbps signal.

We will now discuss the implications of digital broadcast on the Ku- and Ka-band systems.

5.1. Ku BAND

The Ku-band modulation system, delivering 30 Mbps per transponder, is not particularly well-suited to carry 19.4-Mbps digital broadcast signals. Each transponder can carry only a single digital channel, with left-over spectrum available to perform other work. Although it may be possible in the future to adopt a different standard with somewhat more compression, allowing two such channels in a transponder, we will assume (as always, conservatively) that each transponder in the Ku-band satellite can accommodate one 19.4-Mbps digital signal and three analog channels.

along for the ride. Today, thanks to advanced techniques available, allowing null packets to slip by undetected or transmitting any signal that is not crammed full of content is unacceptable...A year ago, for example, Skystream took part in a HDTV-related trial with PBS and Intel Corp.—an investor in Skystream—where empty null packets flowing onto Gateway PCs were filled with IP content by the DBn-26. Olson indicates that while this particular demonstration did not entail a satellite feed, null packets make up to anywhere between 2 to 10 percent of a typical DBV satellite feed. NPO [null packet optimization software that injects data, including IP content, into the MPEG 2 stream after detecting and replacing null packets] finds empty bandwidth, and fills it with data opportunistically. In a typical one-hour HDTV transmission, for example, we can fill 2 percent of the 19.4 Mbps HD feed with the equivalent of approximately 15,000 Web pages...On some satellites using the DVB standard, the presence of null packets can run as high as 30 percent, and yet with statistical multiplexing in place, the number has often been closer to well below 2 percent.

5.1.1. BASIC CONFIGURATION

Currently DirecTV control 46 transponders and EchoStar 50 over the U.S. Therefore, DirecTV can carry 46 digital signals and 138 standard channels, while EchoStar can carry a total of 50 digital signals and 150 standard TV signals.

5.1.2. WITH SHARING

Suppose the two existing carriers were to merge. In this case, there would be no duplication of channels carried so that 96 digital channels and 288 standard channels of programming, whether national broadcast or local stations, could be carried.

5.1.3. WITH SPOT BEAMS

If all capacity were assigned to local carriage, then, using the multiplier of three derived earlier, as many as 288 different digital and 864 standard signals could be carried. If national (non-broadcast) network program services were to remain in standard format, they could be broadcast using 200 of the 288 available standard channels, leaving 288 digital and 264 standard channels (88 times 3) available for local station rebroadcast.

5.1.4. SYNOPSIS

The Ku DBS band, even if upgraded with spot beams and reorganized to use the spectrum more efficiently, has limited capacity to carry digital signals. If large numbers of digital signals are to be carried by satellites, other approaches, such as Ka band systems, must be used.

5.2. Ka BAND

Ka-band satellites have greater carrying capacity than Ku-band satellites, there are potentially more orbital slots available, and they can accommodate greater reuse with spot beams. The transponders, furthermore, can be designed to comport more closely with digital broadcast formats.

To determine the carriage possibilities with existing spectrum allocations and orbital slots, assume (as before) that there are 46 effective transponders deployed per satellite, each of which can handle two digital signals (two times 19.4 Mbps equals almost 39 Mbps, which is the assumed capacity of a transponder). A single satellite could serve 92 digital signals in nationwide broadcast mode (two times 46 equals 92).

If these satellites were used exclusively for local station rebroadcast, then all signals would be transmitted using spot beams. Assuming a reuse factor of eight, then each satellite can carry 368 transponders. At two digital signals per transponder, it can support 736 local digital signals. Therefore, two Ka-band satellites could carry the digital signals of 1,472 local broadcasters, which would reach 149 markets covering 95 percent of the television population. If all markets were to be served, the remaining signals would require an additional satellite. If configured the same way, only a small fraction of the 368 transponders would be required, leaving the remainder for other purposes. Alternatively, the third satellite could be designed for less capacity, at somewhat reduced cost.

6. CONCLUSION

Our analysis of technical feasibility suggests that virtually complete carriage of local television signals—whether digital or analog—is well within the potential productive capacity of DBS systems that can be realistically deployed and efficiently exploited using available technical knowledge and spectrum assignments. This result can be accomplished consistent with maintenance of quite substantial capacity for other purposes, including delivery of large quantities of other types of video programming, different types of data and broadband Internet access service. Our conclusion rests primarily on timely deployment of advanced satellites in the Ku and Ka bands utilizing spot-beam technology.²⁰ This is precisely what the DBS carriers appear to be doing. At the end of 1999, Eddy Hartenstein, president of DirecTV stated:²¹

²⁰ Still more capacity can be made available if an efficient rationalization of carriage that conserves (*i.e.*, does not waste) carrying capacity is adopted.

²¹ See Hughes Space and Communications Company Press Release (8/12/99): "DIRECTV Orders High-Power Spot Beam Satellite From Hughes Space & Communications—DIRECTV-4S Satellite to Provide Additional Local Channels and Strengthen In-Orbit Redundancy."

With the passage of the Satellite Home Viewer Improvement Act, the last barrier for consumers to purchase satellite TV has finally been lifted. Investing in spot beam technology will benefit our customers and enable us to add additional local channels in markets we are already serving or plan to serve, as well as extend local channel services to additional smaller markets.

As noted earlier, both DirecTV and EchoStar plan to deploy satellites with spot-beam technology. Local TV on Satellite (“LTVS”) has also announced that it plans to uplink approximately 800 local digital broadcast stations for delivery to DBS subscribers.²² The LTVS service appears as if it could easily function as a “carriers’ carrier” and afford a technically and economically efficient means of delivering local signals and helping to meet legal carriage requirements.

²² See LTVS News Release (4/19/00): “New Local TV DBS Satellite System Proposed,” *Space Tech* (April, 24, 2000).